VALVES
AND
VALVE PROBLEMS

A PRESENTATION BY

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VALVES AND VALVE PROBLEMS

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Throughout the design, manufacturing, and testing phases of the various space boosters, major problems have always existed which have been realized by only those people directly involved. Most people within the aerospace industry are constantly aware of the structure, guidance, and propulsion groups, but fail to recognize that small, specially developed commercial valves and switches could well be, and often are, the key to a success or failure.

Experience gained at MSFC has indicated that practically no type valve manufactured by a vendor, regardless of whether it is a vendor or MSFC design, has performed at 100% reliability. The reasons for this are many, one being the fact that environmental conditions are hard to simulate at the vendor's plant for a complete hardware checkout.

Table 1 indicates the topics to be presented during the discussion on valves and the many problems connected with them.

Practically all valves at MSFC have been designed for a specific purpose. This is accomplished by MSFC design and the valve vendors.

The Valve Manufacturing Phase (Table 2) is initiated after all specifications and drawings have been released for production. The valves are procured from the vendor according to the quantity required and the scheduled completion date of the launch vehicle. At present, procurement includes not only the valves but: (1) complete vendor drawings, (2) service instructions, (3) required assembly tooling, (4) recommended spare parts list, (5) and a training program for MSFC technicians. During valve manufacturing, close liaison is maintained

VALVES AND VALVE PROBLEMS

1. MANUFACTURING PHASE
2. FAILURE EVALUATION
3. PROBLEMS
4. VALVE CLINIC

TABLE 1. VALVES AND VALVE PROBLEMS

VALVE MANUFACTURING PHASE

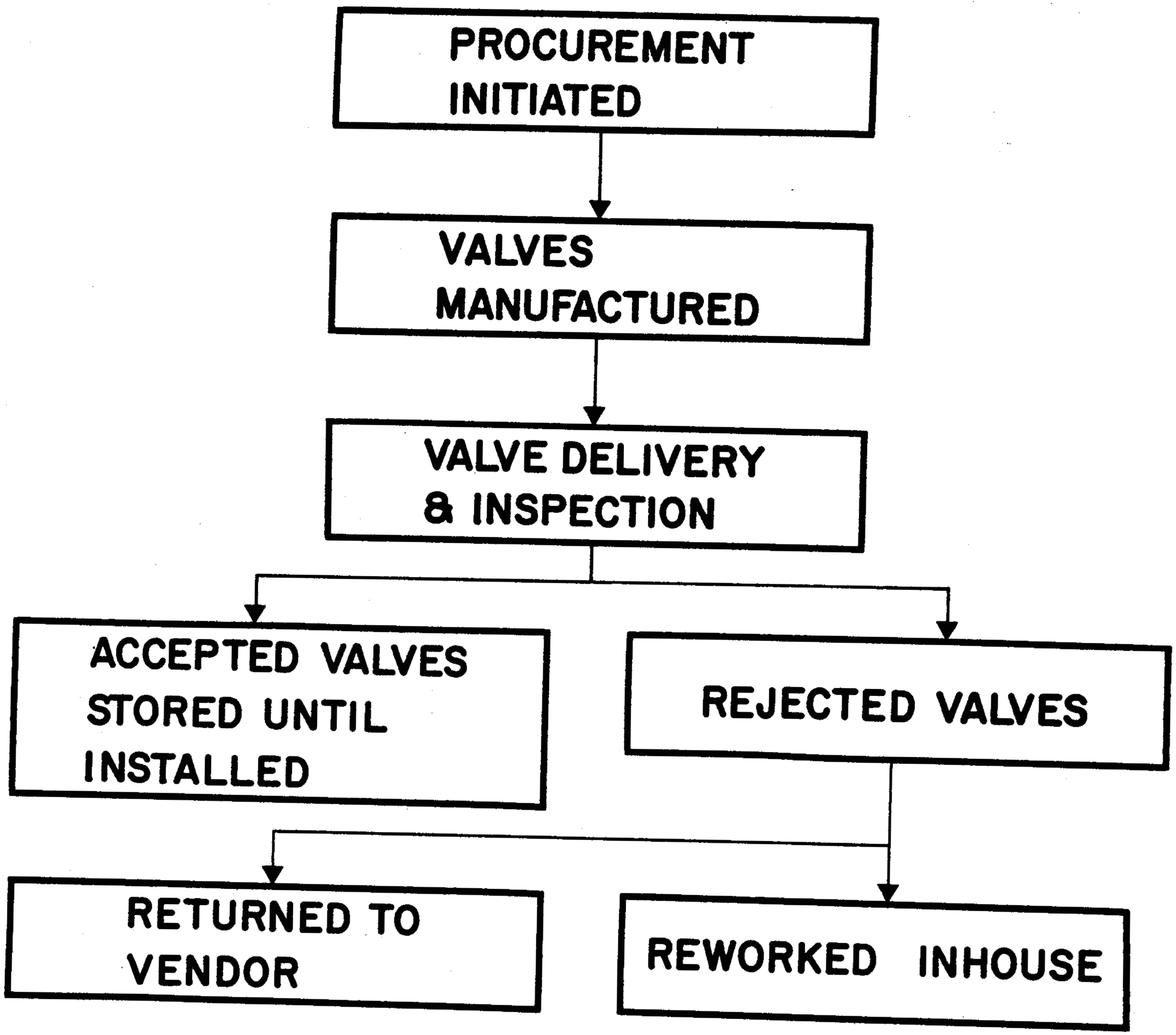

TABLE 2. VALVE MANUFACTURING PHASE

between the vendors and MSFC to assure that the scheduled delivery date is met and to be cognizant of any manufacturing problems. Upon delivery each valve is inspected and functionally checked. All accepted valves are stored until needed for installation. Rejected valves are either returned to the vendor if the schedule permits or reworked in-house.

Valve performance testing is a coordinated effort of the MSFC Quality Division and the Valve Clinic. It has been found that some missile manufacturers do not always perform this phase of testing. The valve is simply removed from its packing crate and installed.

Whenever a valve fails during a test on the vehicle a Failure Evaluation (Table 3) is conducted. Failure could result from either defective material or workmanship not discovered during inspection, or subjection to adverse conditions for which it was not designed. After the inspector has issued a formal rejection slip, the replacement is accomplished and the rejected valve is routed to Failure Investigation where the exact cause of failure is determined. The philosophy of MSFC is to determine the exact cause of all valve failures on the vehicle in order that corrective action can be initiated to insure against future failure. The report issued by Failure Investigation indicates the necessary action to be taken. If the valve failed due to a manufacturing problem, it is coordinated with the vendor for correction. Design problems are coordinated with both MSFC Design and the vendor.

The Manufacturing Phase and Failure Evaluation have been discussed. (Some examples of valve failures at MSFC and the corrective action taken follows.)

A number of problems were encountered in the Gas Bearing Supply Regulation System. This system has the requirement to furnish gaseous nitrogen to the

FAILURE EVALUATION

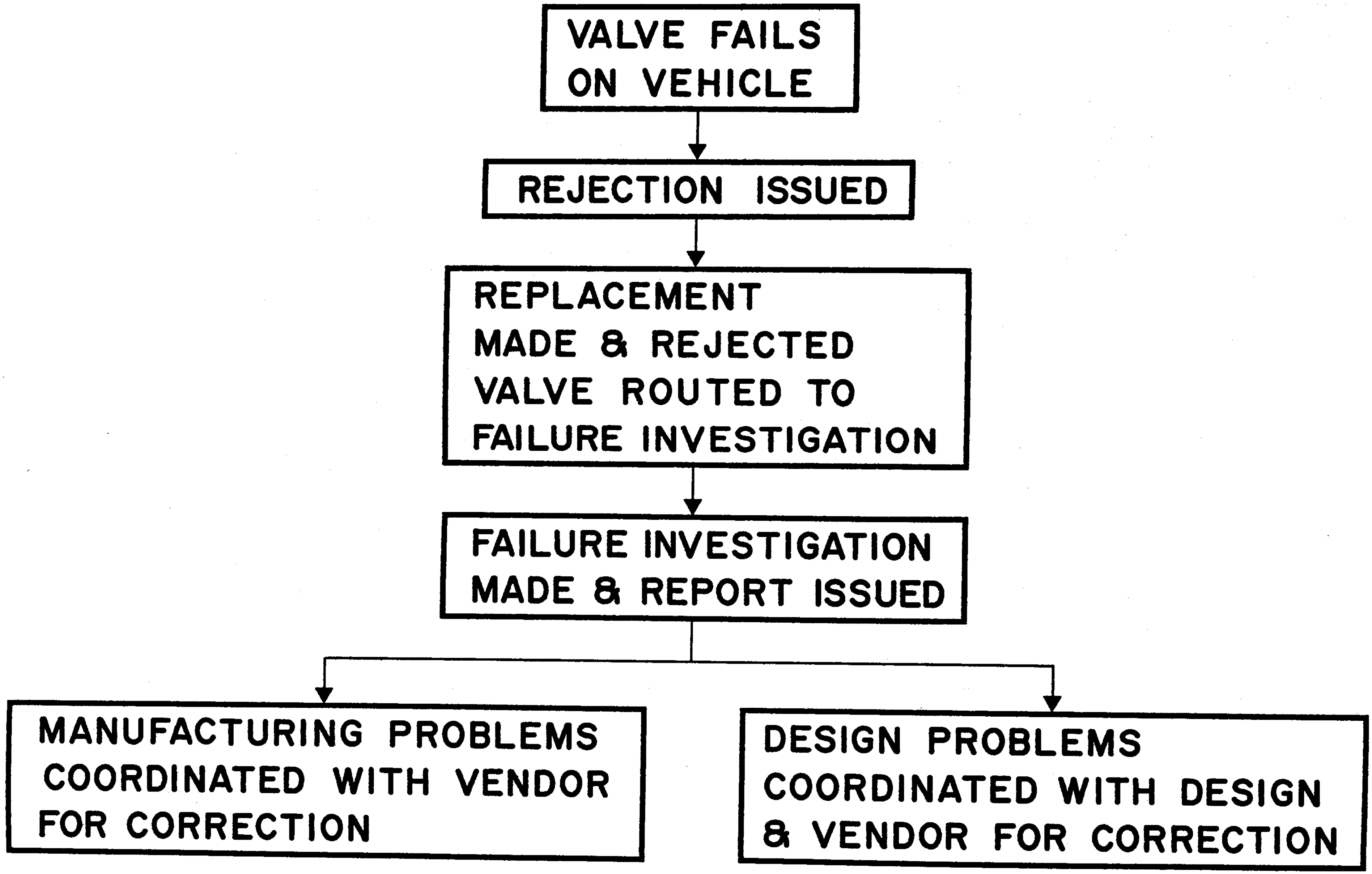

TABLE 3. FAILURE EVALUATION

guidance gyros at a specific pressure, flow, and temperature. To accomplish this task the Regulator System is composed of the following critical items: (1) a two-stage regulator, (2) filter, (3) heater, (4) thermostat, (5) relay, (6) orifice and solenoid by-pass. A workable regulation system was available during the Redstone and Jupiter era for those vehicles, but the introduction of the Saturn brought forth additional requirements for weight reduction, compactness, and cleanliness.

Figure 1 shows a breadboard model of the Block I Saturn configuration of the Gas Bearing Supply System. The Redstone and Jupiter, the Block I Saturn, and the Block II Saturn Gas Bearing Supply Regulation System configurations are shown in Figures 2, 3, and 4, respectively. The three systems are shown in Figure 5. The Block I Saturn configuration (Figure 3) constituted the first major design change by consolidating the two individual regulators and the solenoid and orifice by-pass into one integral unit.

A recent problem with this system involved the position of the thermostat. Due to its close location to the heater the thermostat cycled continually, causing a decrease in gas temperature. The solution to this problem involved relocating the thermostat to a position downstream of the regulator.

Figure 6 shows the electrical terminals in the regulation system. The insulation resistance broke down when the temperature of the regulator was elevated. The cause of this problem was found to be defective electrical insulator terminals which were replaced with terminals known to withstand the required temperature.

A failed diaphragm in the first stage end of the regulator is shown in Figures 7, 8, and 9. The diaphragm burst due to the sharp edge on the diaphragm

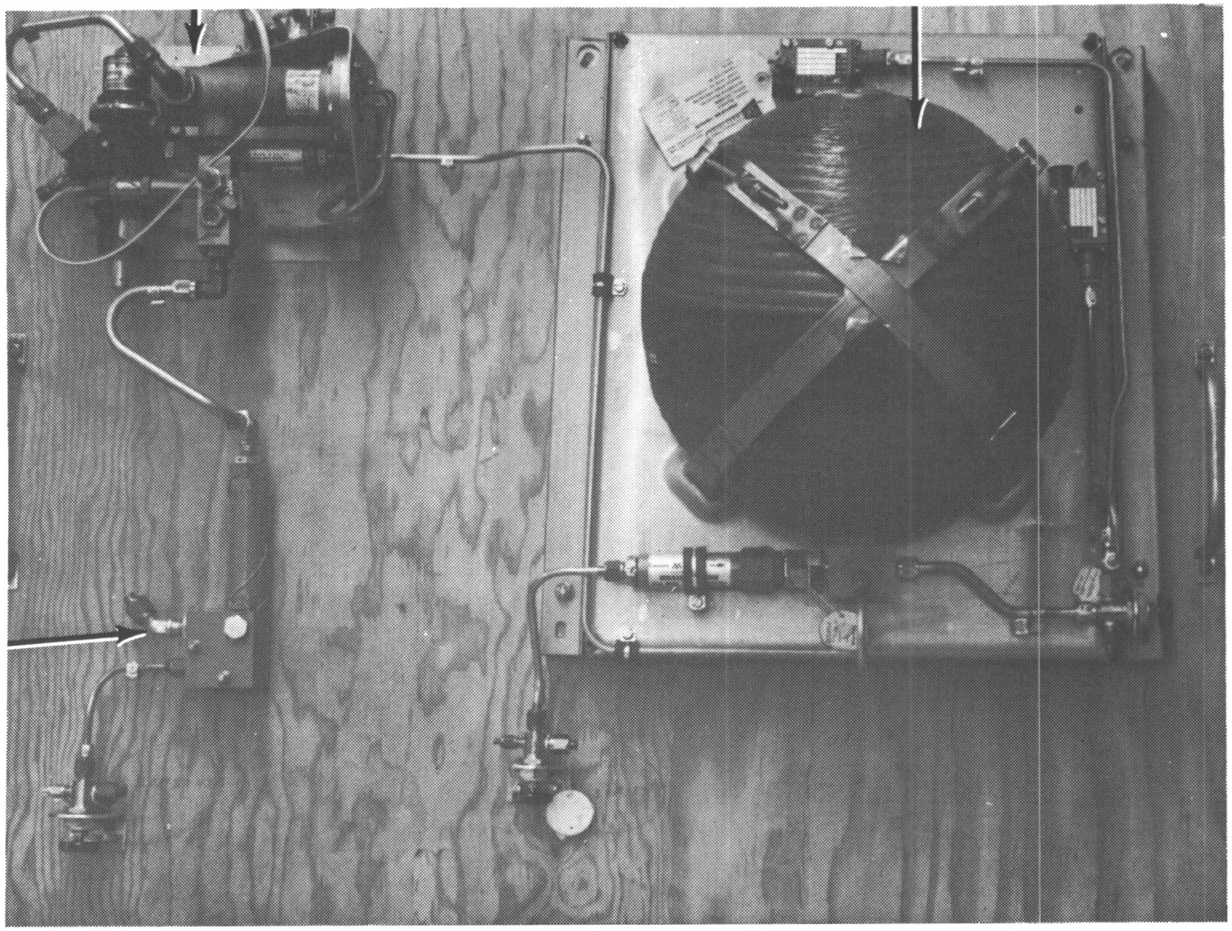

FIGURE 1. GAS BEARING SYSTEM - BREADBOARD MODEL

FIGURE 2. GAS BEARING SUPPLY REGULATION SYSTEM FOR REDSTONE AND JUPITER

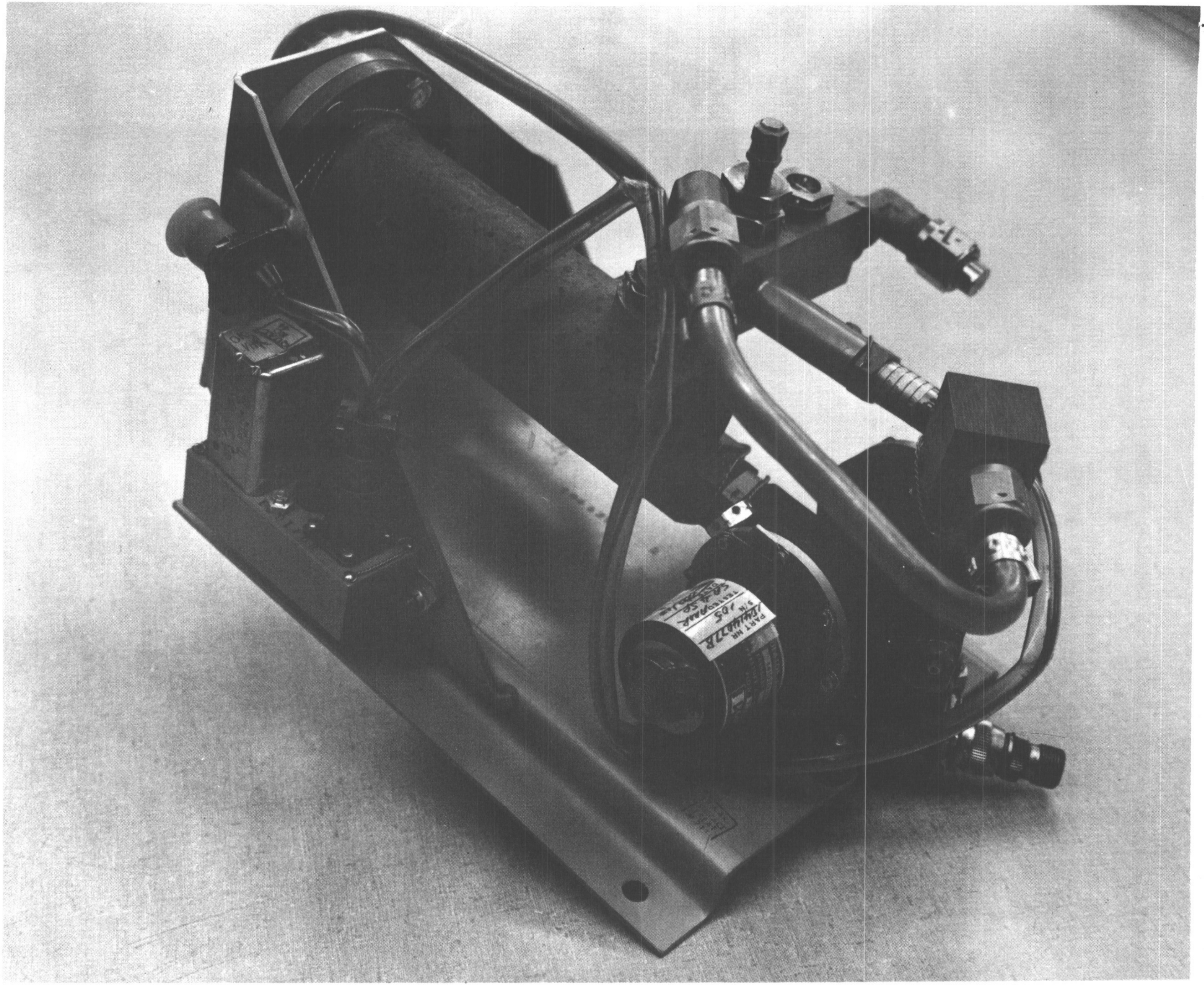

FIGURE 3. GAS BEARING SUPPLY REGULATION SYSTEM FOR BLOCK I SATURN

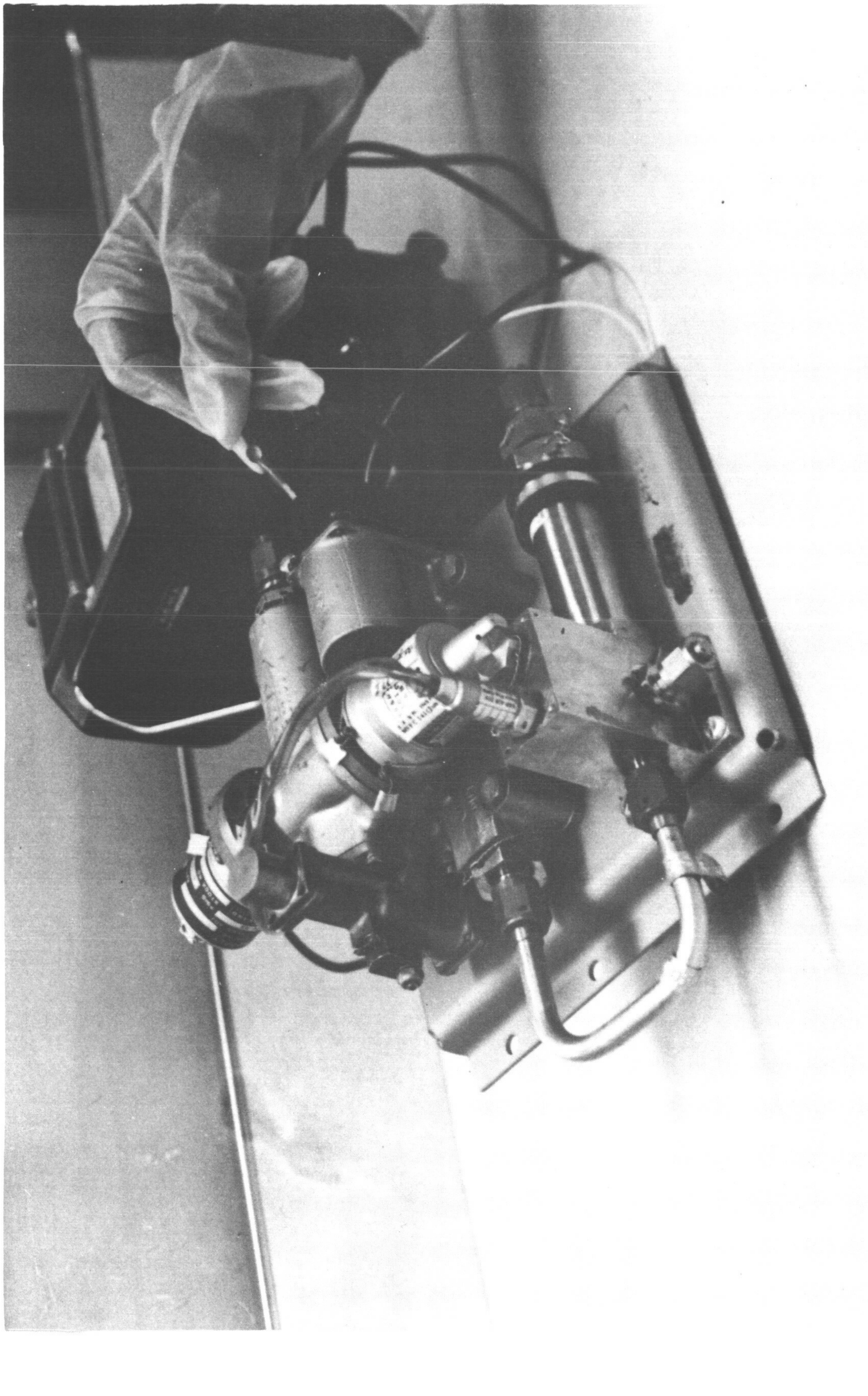

FIGURE 4. GAS BEARING SUPPLY REGULATION SYSTEM FOR BLOCK II SATURN

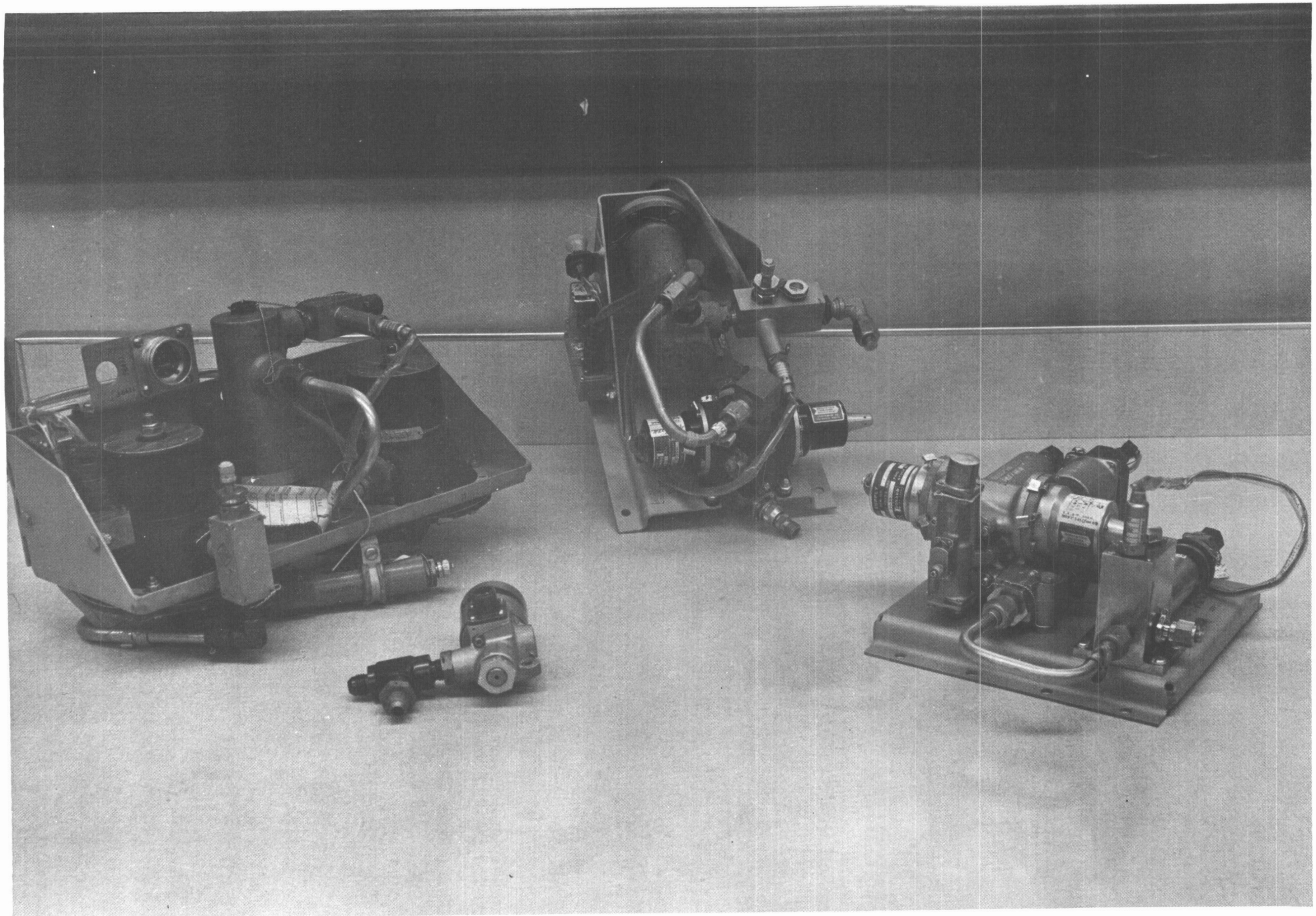

FIGURE 5. GAS BEARING SUPPLY REGULATION SYSTEMS FOR REDSTONE AND JUPITER, BLOCK I SATURN, AND BLOCK II SATURN

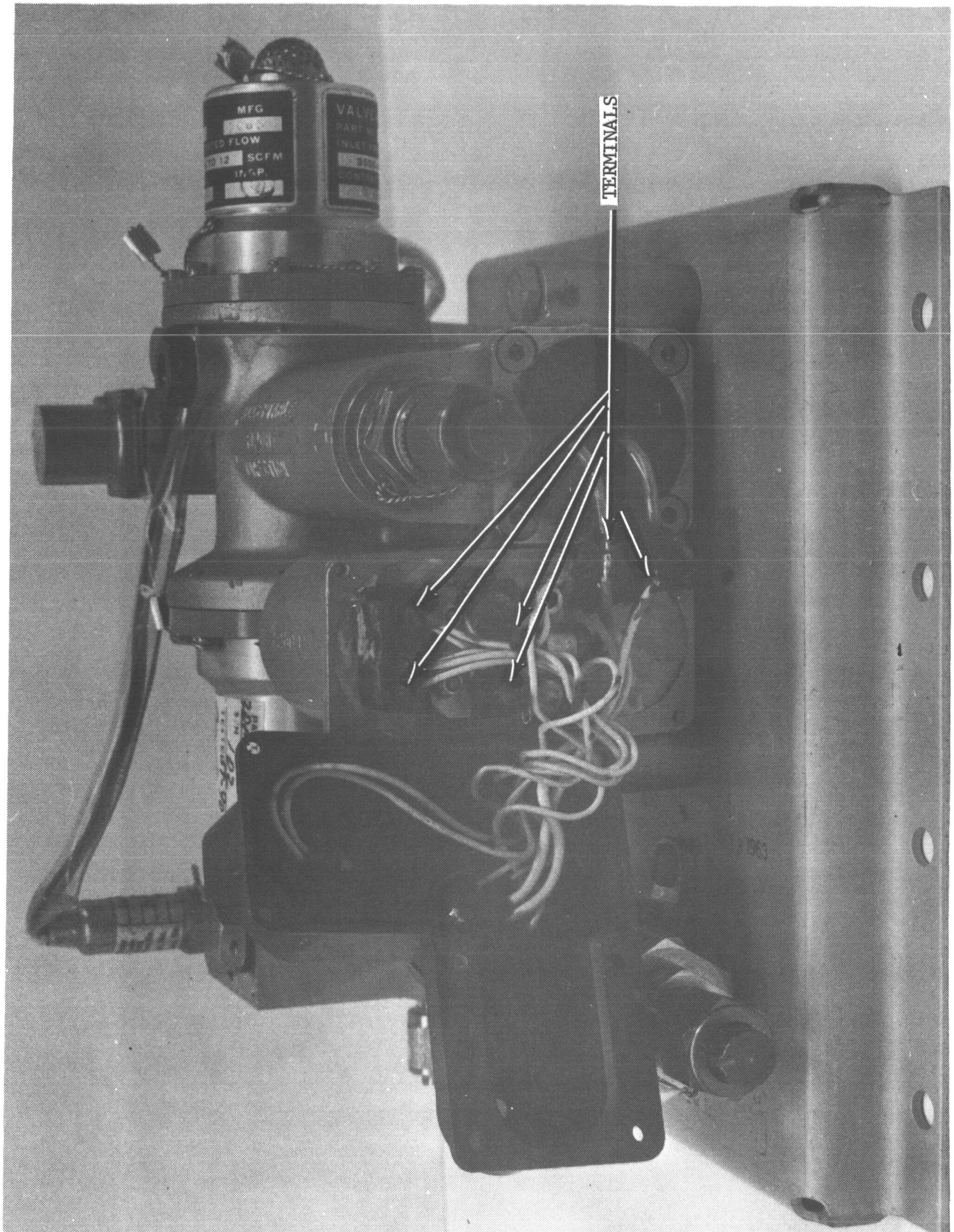

FIGURE 6. ELECTRICAL TERMINALS OF BLOCK II SATURN GAS BEARING SUPPLY REGULATION SYSTEM

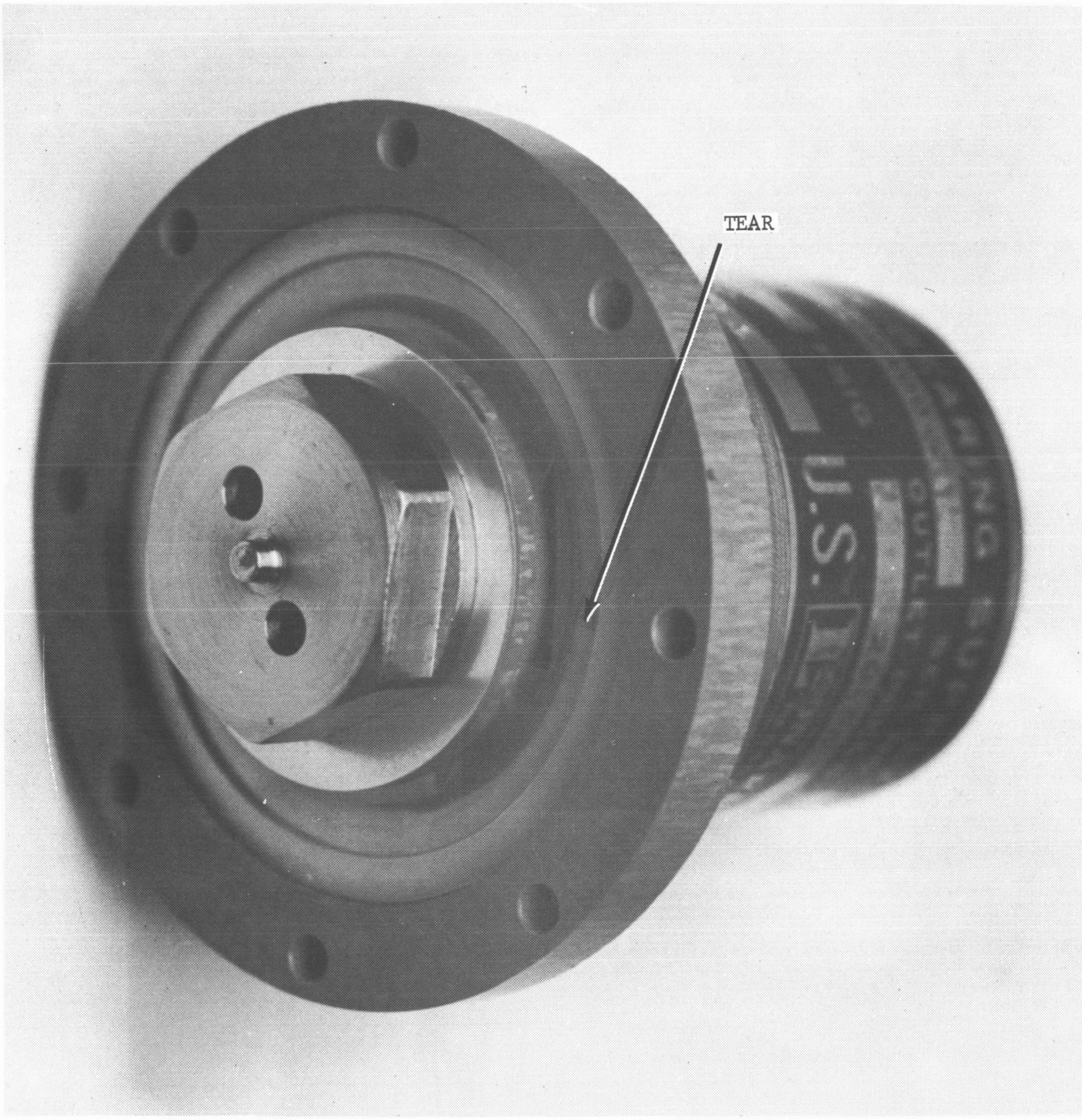

FIGURE 7. REGULATOR - FIRST STAGE PORTION - BROKEN SEAL

WRINKLE

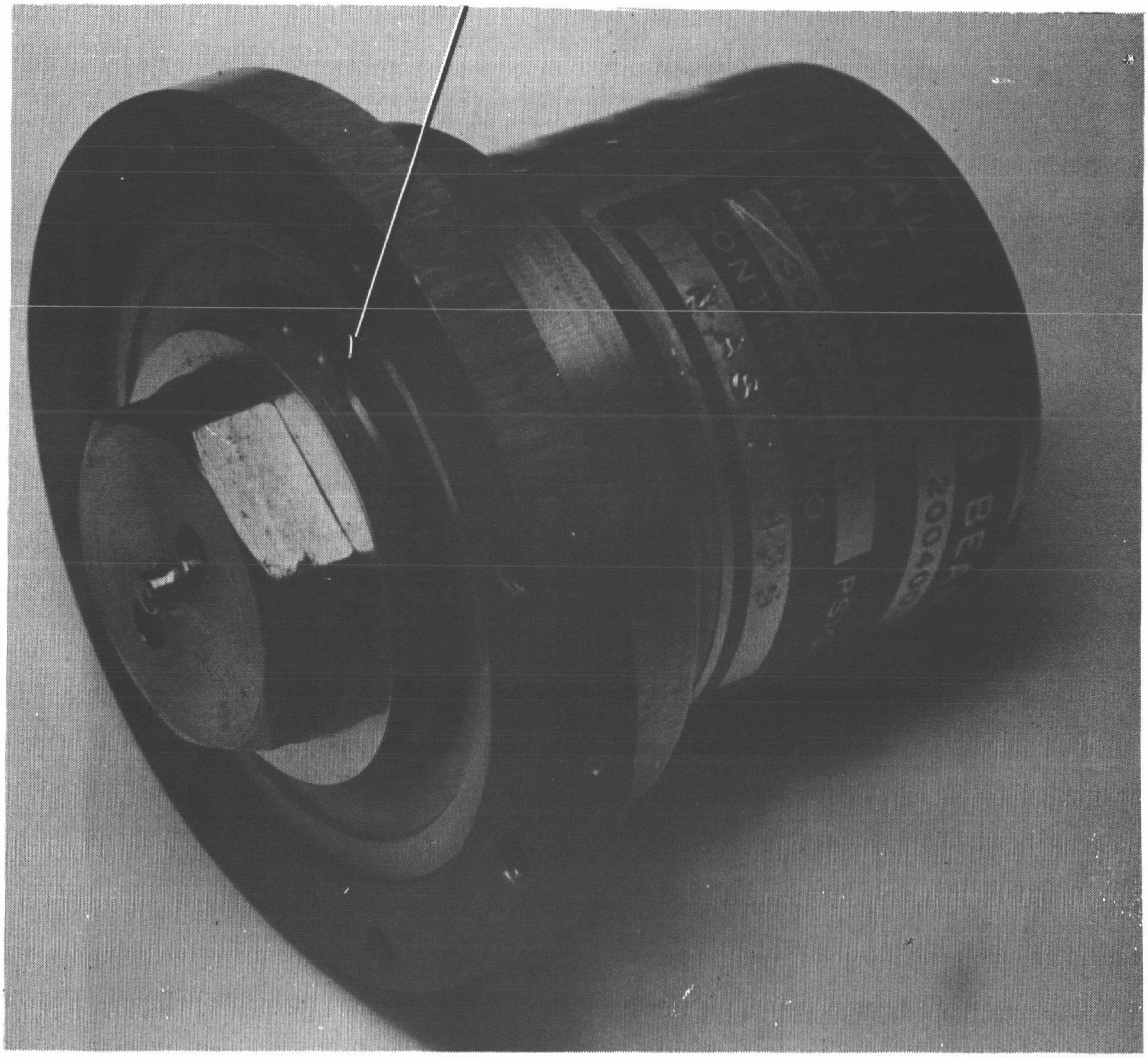

FIGURE 8. REGULATOR - FIRST STAGE PORTION - WRINKLED SEAL

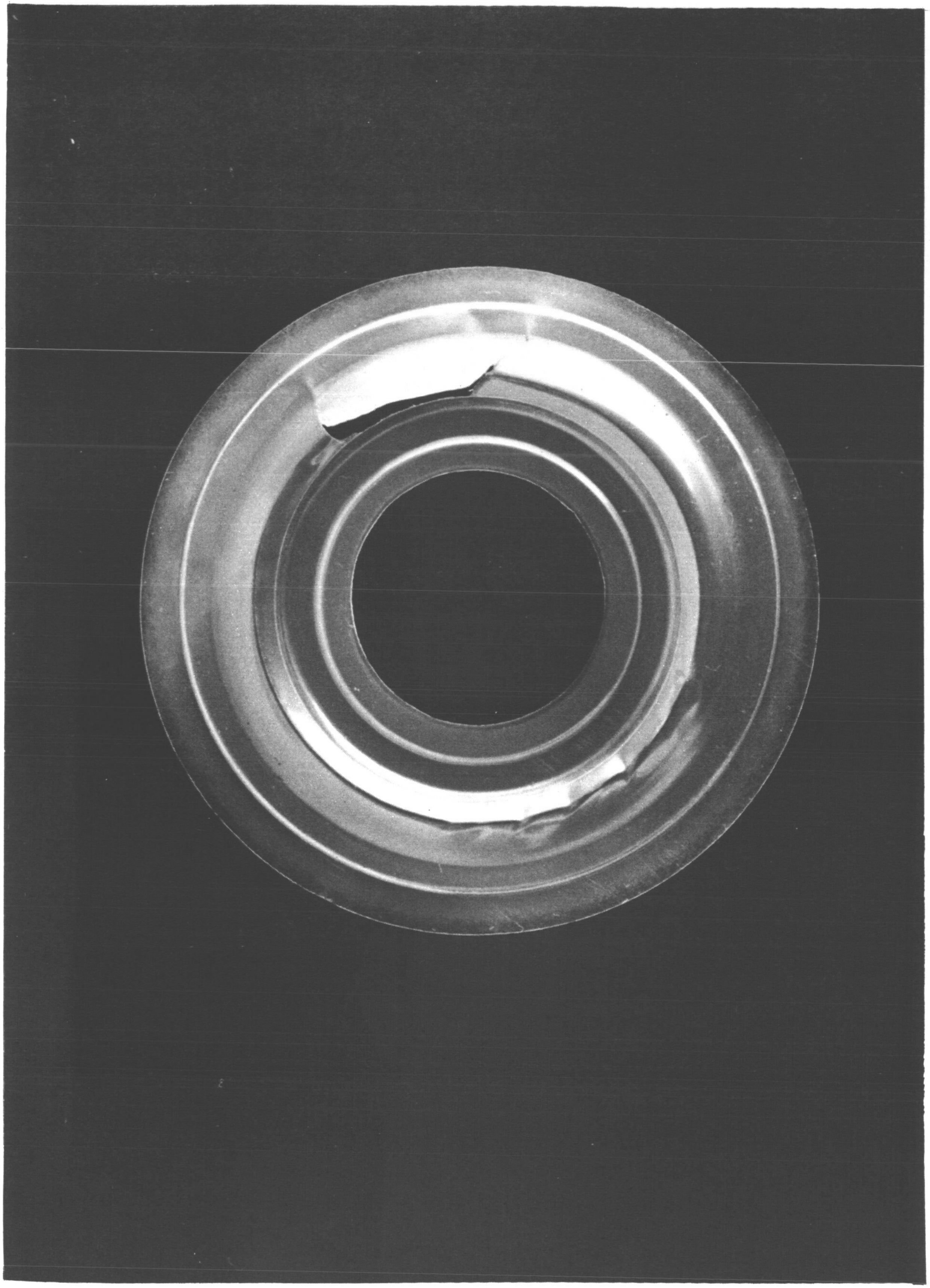

FIGURE 9. DAMAGED REGULATION SEAL

retainer and wrinkles in the diaphragm itself. This problem was corrected by removing the sharp edge on the retainer and modifying the forming process of the diaphragm to eliminate the wrinkles.

A problem was also encountered with the LOX Heat Exchanger Check Valve. The LOX containers on the Saturn Vehicle are pressurized during flight by LOX which has passed through the rocket engine heat exchangers. Within this pressurizing system, check valves are located between the heat exchangers and the LOX containers. On the Block I Saturn vehicles no major problems with these check valves were encountered, but on the Block II Saturn the check valves were exposed to a higher temperature which caused external leaking during the static firing of SA-5. This increased heat caused the Teflon seal between the valve body halves to flow out of shape causing the valve to leak (Figure 10). This problem was corrected by changing the material of the housing seal from Teflon to copper (Figure 11).

The Saturn LOX Container Pressure Relief Valve (Figure 12) has experienced more problems and a higher rejection rate since the Redstone vehicle than any other valve. Most of these problems were excessive leakages at cold temperatures.

One problem involved the fact that the valve would not maintain the relief setting, which caused excessive leakage through the main seat (Figure 13). This seat consisted of a tapered rigid poppet seating inside a lip seal. This situation was corrected by replacing the lip seal with a solid Kel-F seal machined on the I.D. to fit the taper of the poppet and redesigning the poppet so that it would swivel for alignment purposes.

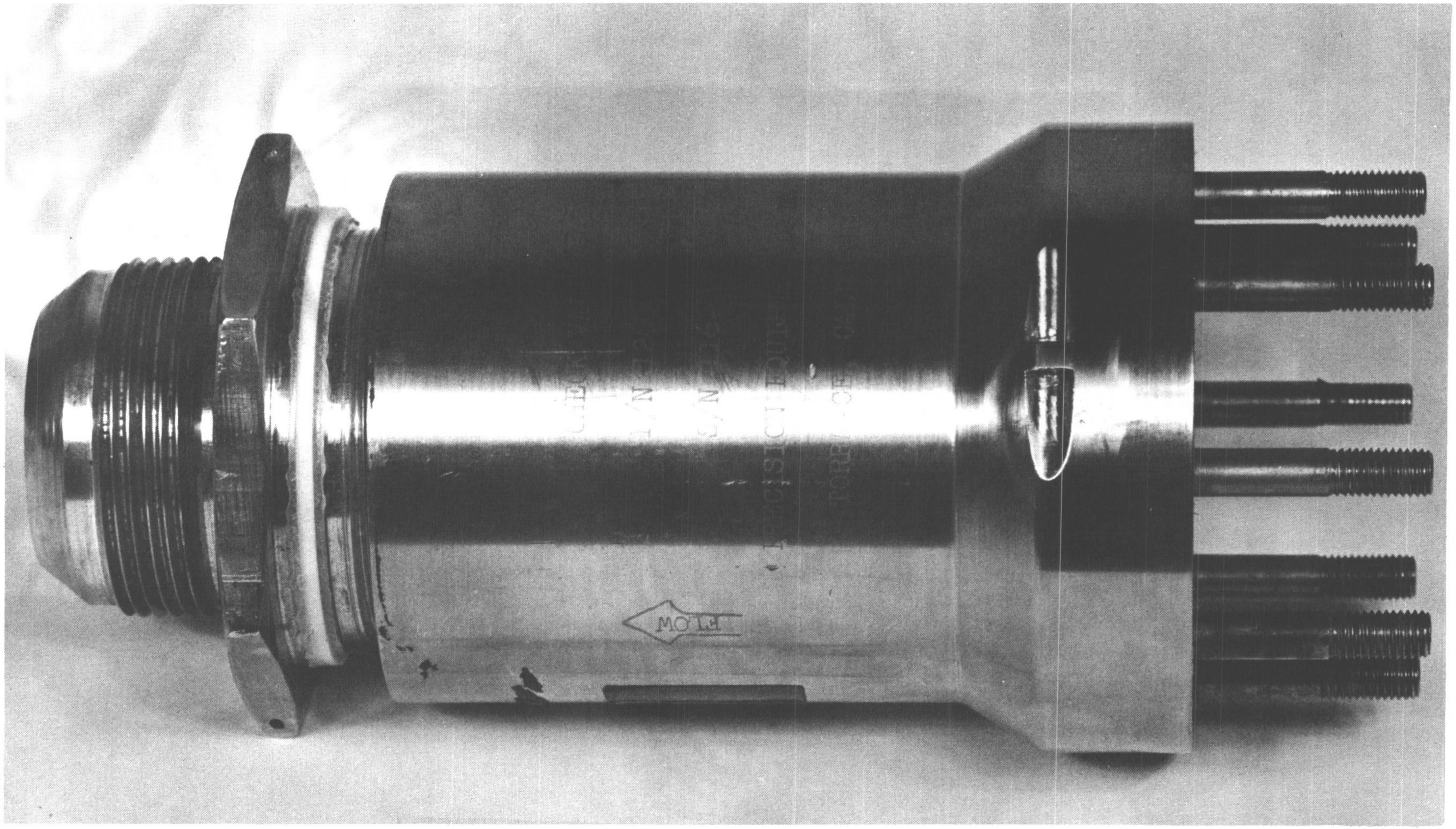

FIGURE 10. LOX HEAT EXCHANGER CHECK VALVE

FIGURE 11. REPLACING OF TEFLON SEAL WITH COPPER SEAL

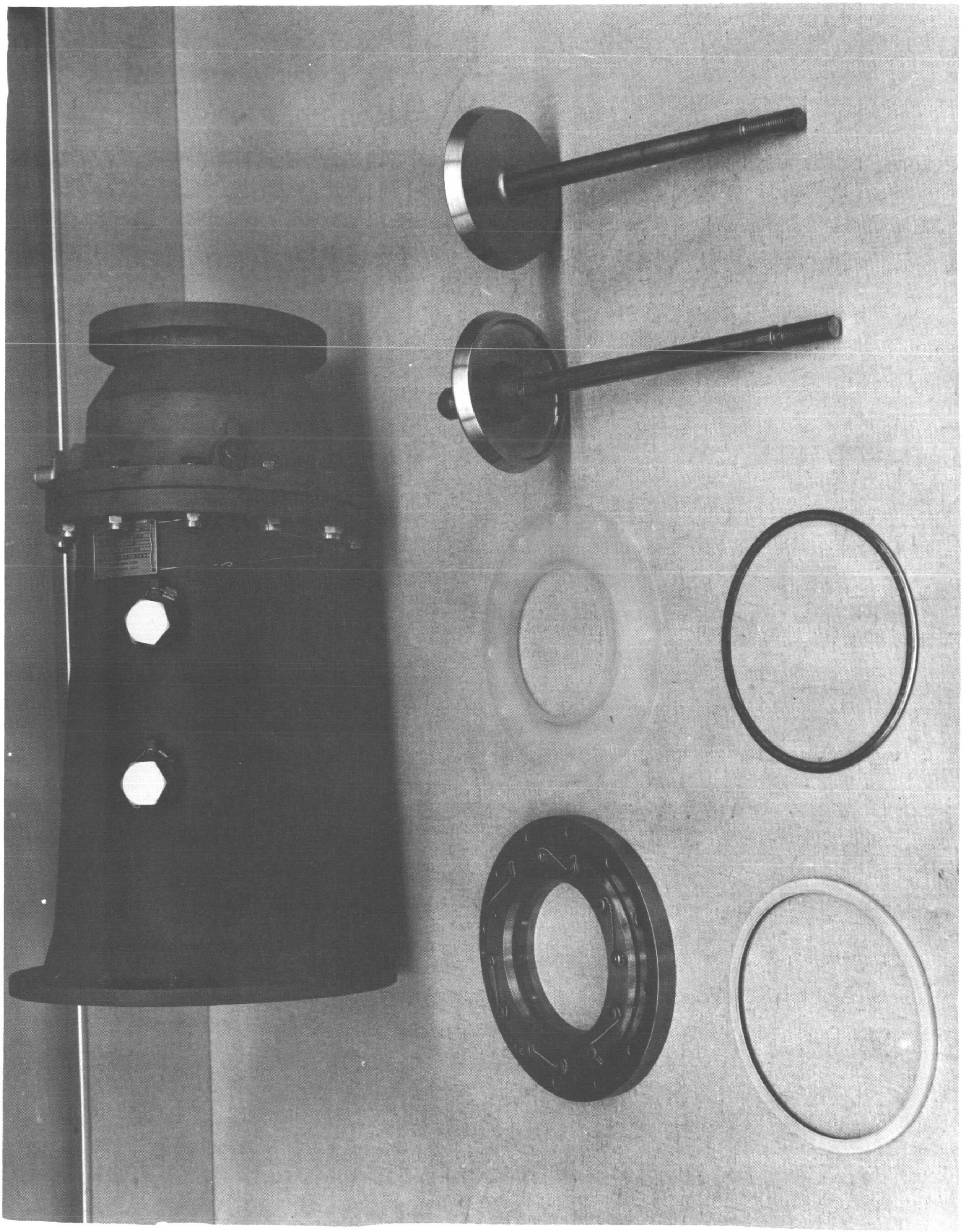

FIGURE 12. SATURN LOX CONTAINER PRESSURE RELIEF VALVE

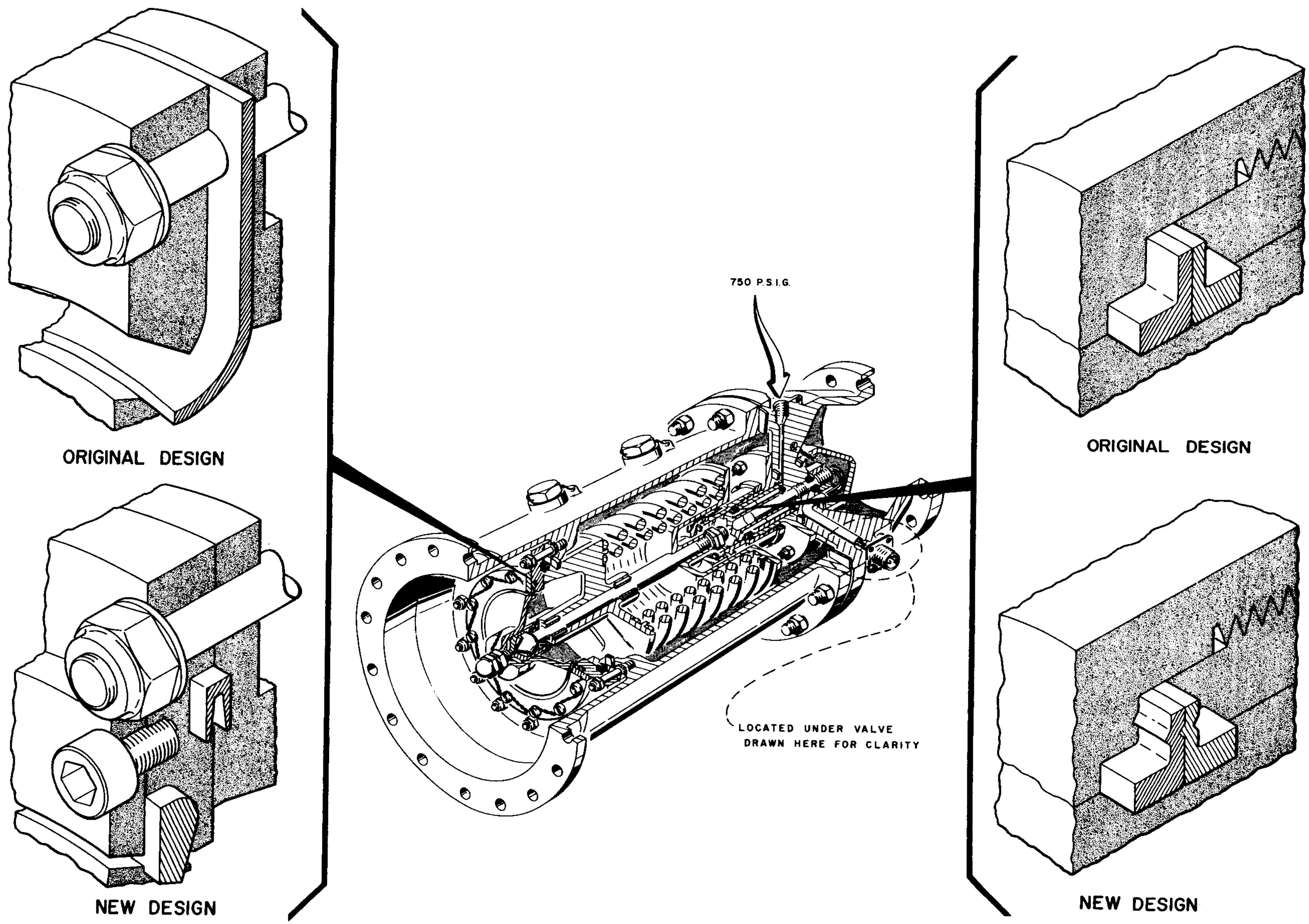

FIGURE 13. LOX RELIEF VALVE DESIGN CHANGES

Another problem concerned the potting compound in the electrical position indicator switch. This potting compound absorbed moisture, causing the switch to short. All available potting compounds compatible with LOX also had a tendency to absorb moisture, consequently the solution to this problem had to involve the use of two different types of potting compound. A potting compound which was not compatible with LOX but water proof was used inside the switch and then capped with a LOX compatible potting compound.

A problem was also encountered in the installation of the indicator switch. This switch is sealed by an O-ring which tends to leak at low temperatures. This leakage has been curtailed by installing an oversized O-ring, but a permanent solution has not been found at the present time.

During testing with temperatures up to 160° F the lip seals around the control piston tend to leak excessively. This leakage has been reduced by incorporating a "V" groove in the joint between the cylinder and the lip seals. This continues to be a problem and as yet no solution has been reached.

Another leak was found in the asbestos (Alpax material) gasket between the valve housing halves. This leakage is caused by the porous nature of the material and has been reduced by impregnating the gasket with Flourlube and by retorqueing the housing connection several times during the assembly process.

On the Block II Saturn Vehicles the same type valves are used as Pre-Valves in the engine feed lines and as container fill and drain valves in both the LOX and fuel systems. The only difference between the LOX and Fuel valves is a slight modification in the LOX valve so that it will operate in cold temperatures (Figure 14).

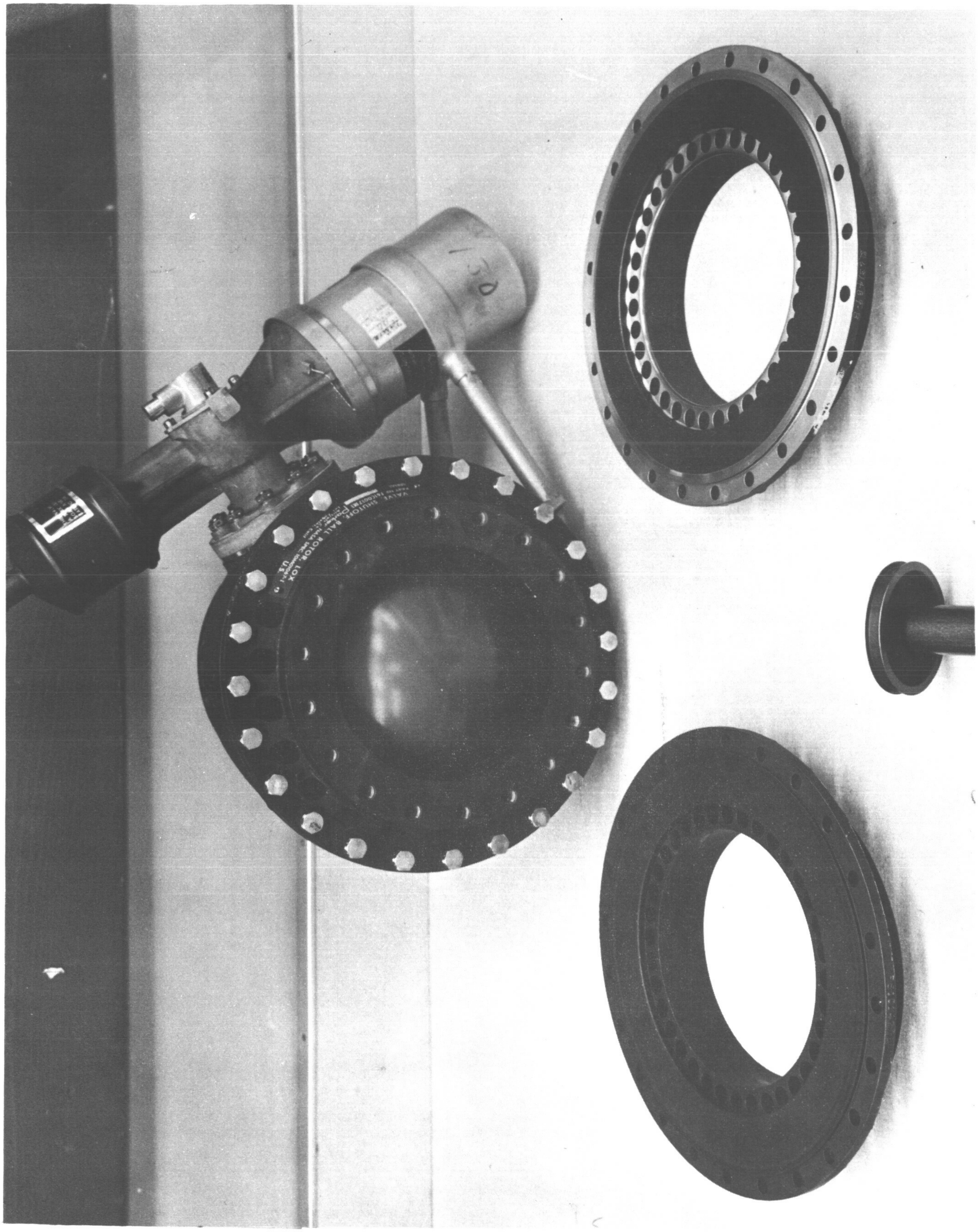

FIGURE 14. LOX CONTAINER FILL AND DRAIN VALVE

One problem with this valve occurred when the main seal leaked LOX during the static firing of SA-5. The cause of this failure was found to be a split in the outer portion of the main seal (Figure 15). The cause of the split was found to be the serrated design of the flange which secures the O.D. of the main seal. These male serrations would cut into the seal to prevent leakage. Because the main seal is made of Teflon, which has a tendency to flow under pressure, the male serrations cut sufficiently into the seal so that the pressure imposed on the valve during static tests caused the seal to split. The solution to this problem was to reverse the serrations. The male serrations were removed and female serrations machined into the flange (Figure 16).

Another problem was encountered when the control system leaked excessively past the piston O-ring. This was caused by the O-ring groove design in the piston (Figure 16). The old design consisted of a small Teflon bearing located on each side of the O-ring. During operation of the valve the Teflon bearings would twist, causing the O-ring to leak. This problem was corrected by modifying the O-ring installation so that the O-ring had only one large Teflon bearing (Figure 16).

Also, the shaft seal has a tendency to leak excessively. At this time a solution is not available for this problem.

Figure 17 shows the cause of a leaky check valve. A metallic chip was lodged on the main seat.

Figures 18 and 19 show a contamination problem caused by metallic chips. The chips were caused by the bad installation of the self locking thread device. The self-locking device consisted of a small nylon plug inserted in a hole drilled in the threads of the male fitting (Figure 18). It was found that the

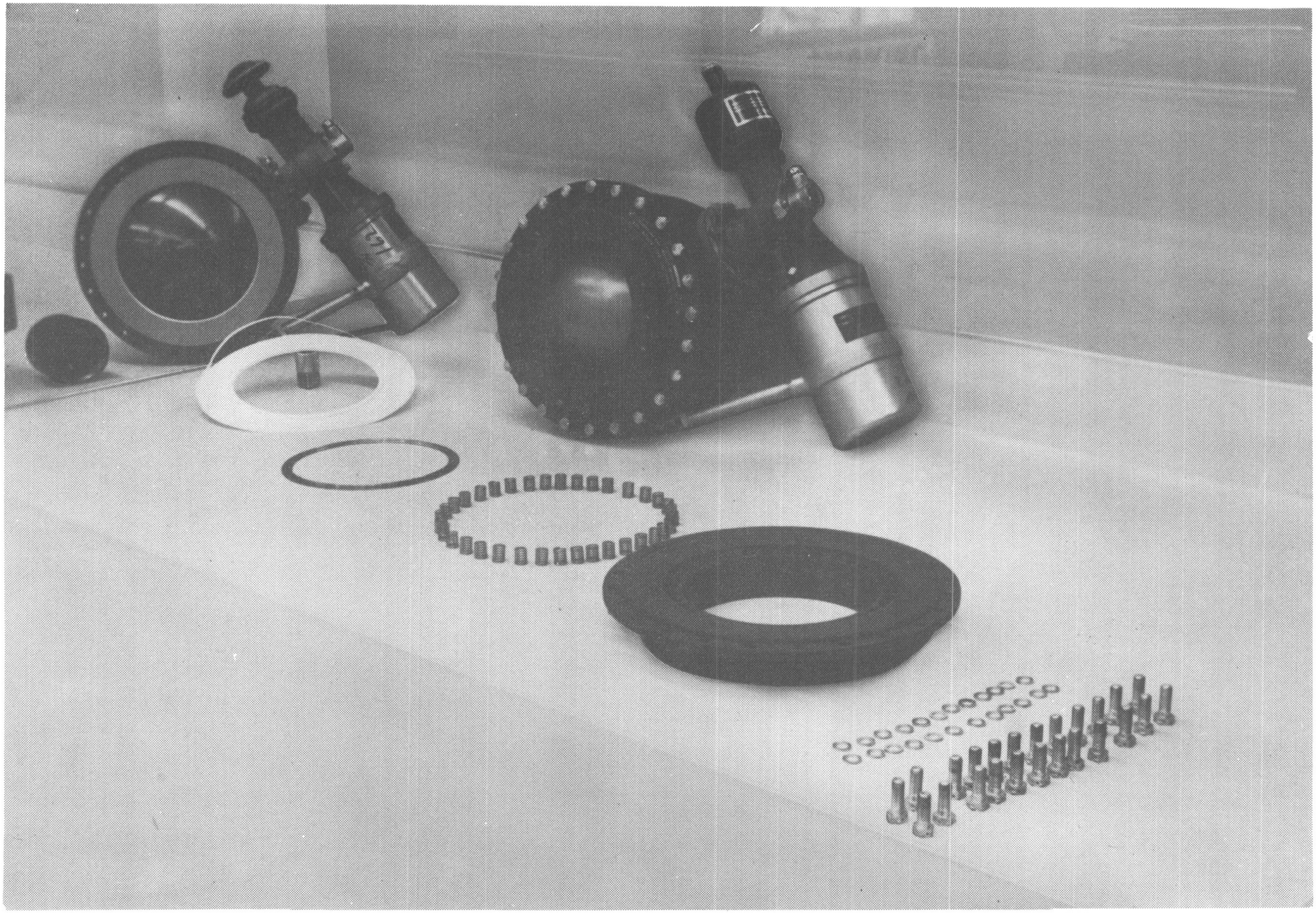

FIGURE 15. CONTAINER FILL AND DRAIN VALVE WITH DAMAGED SEAL

LOX FILL AND DRAIN VALVE (20M30042) DESIGN CHANGES

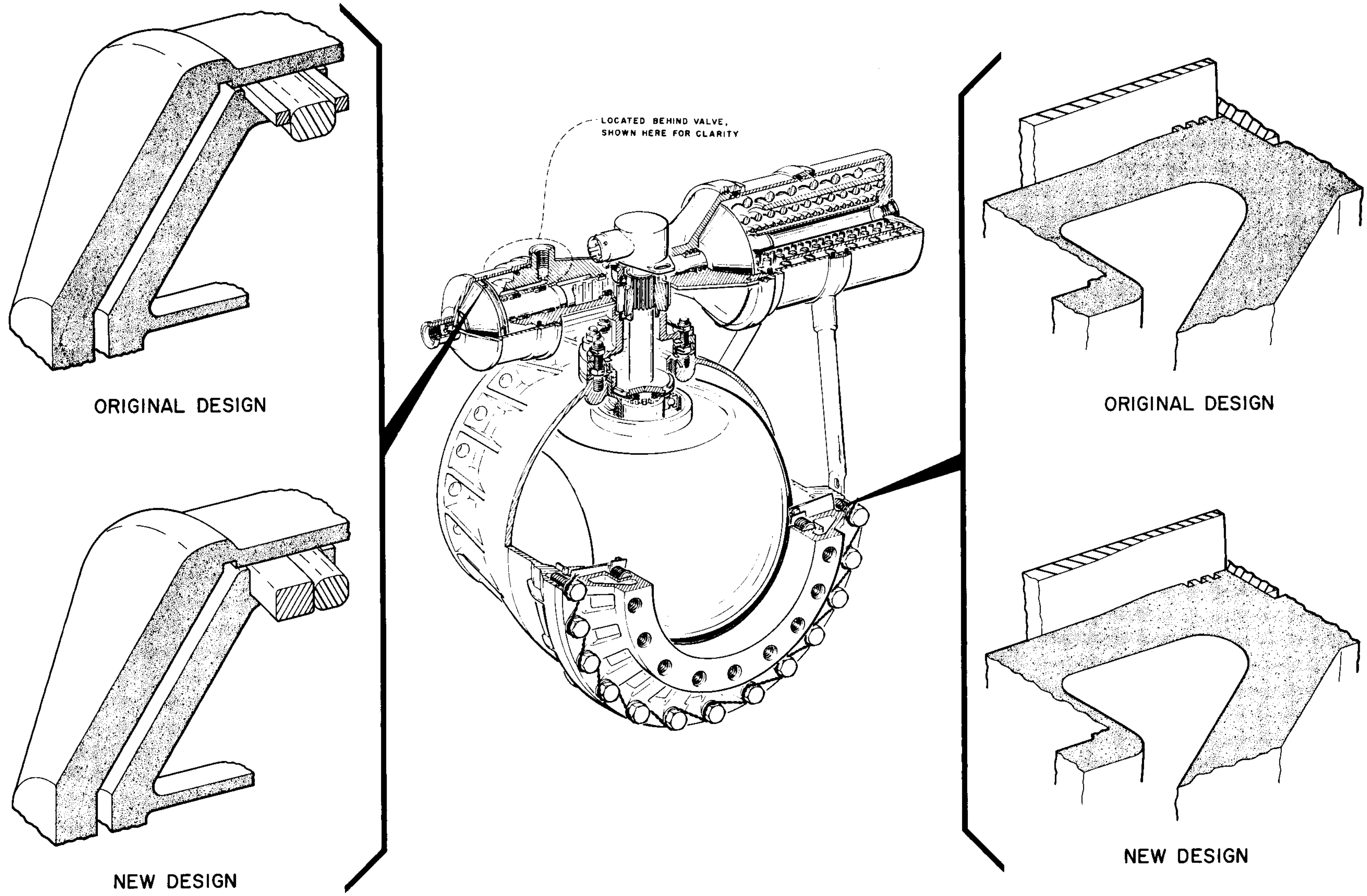

FIGURE 16. LOX FILL AND DRAIN VALVE DESIGN CHANGES

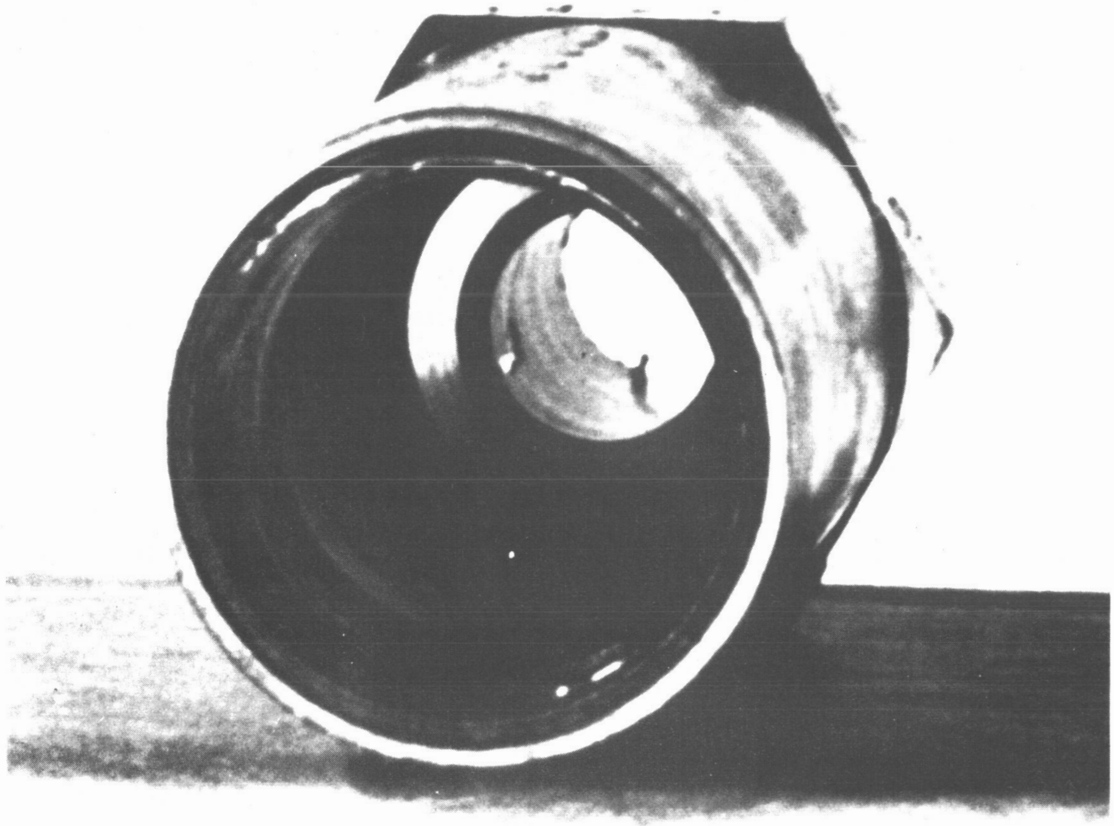

FIGURE 17. CHECK VALVE WITH METALLIC CHIP

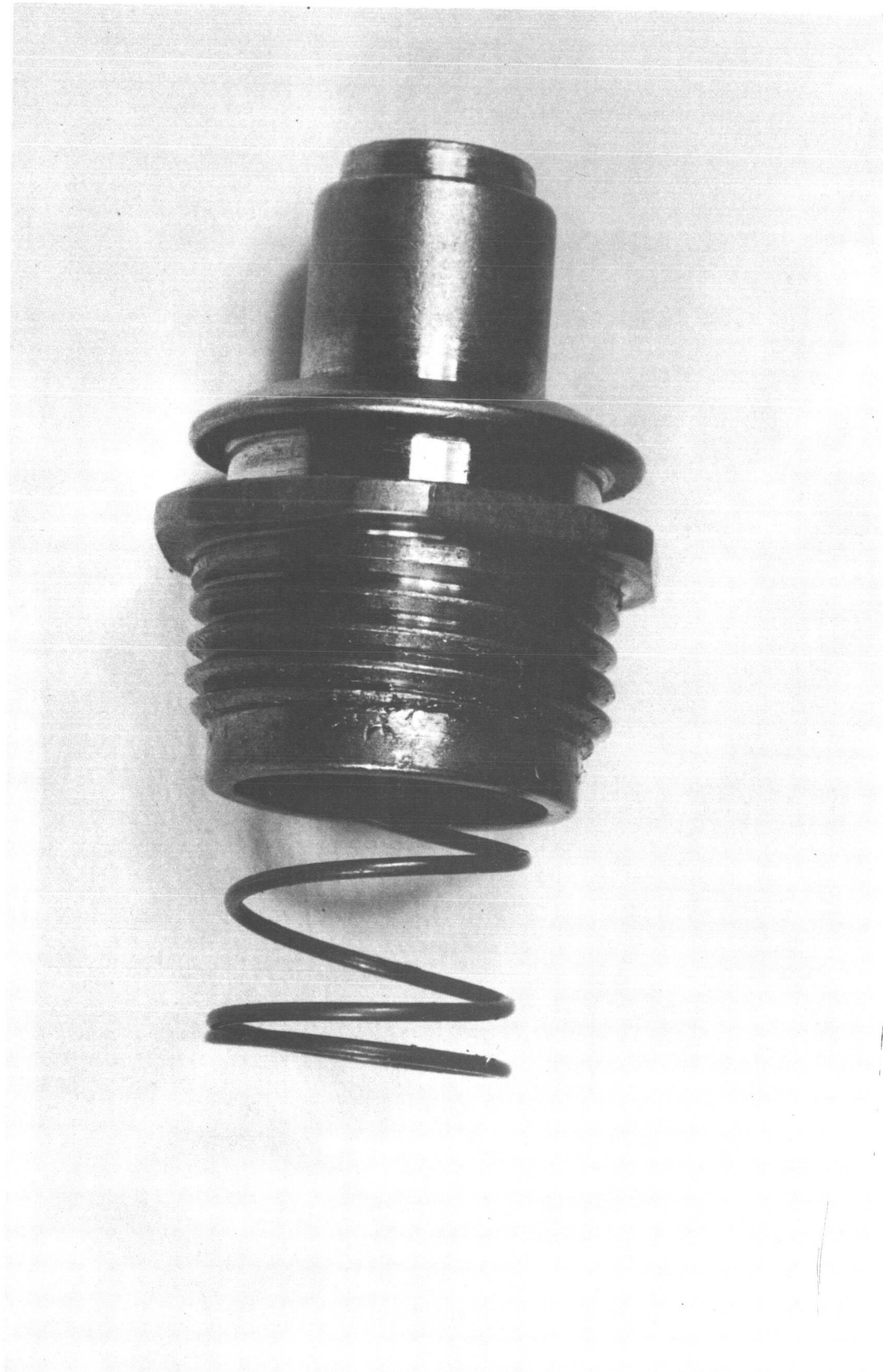

FIGURE 18. METAL CHIP CONTAMINATION ON EXTERNAL THREADS

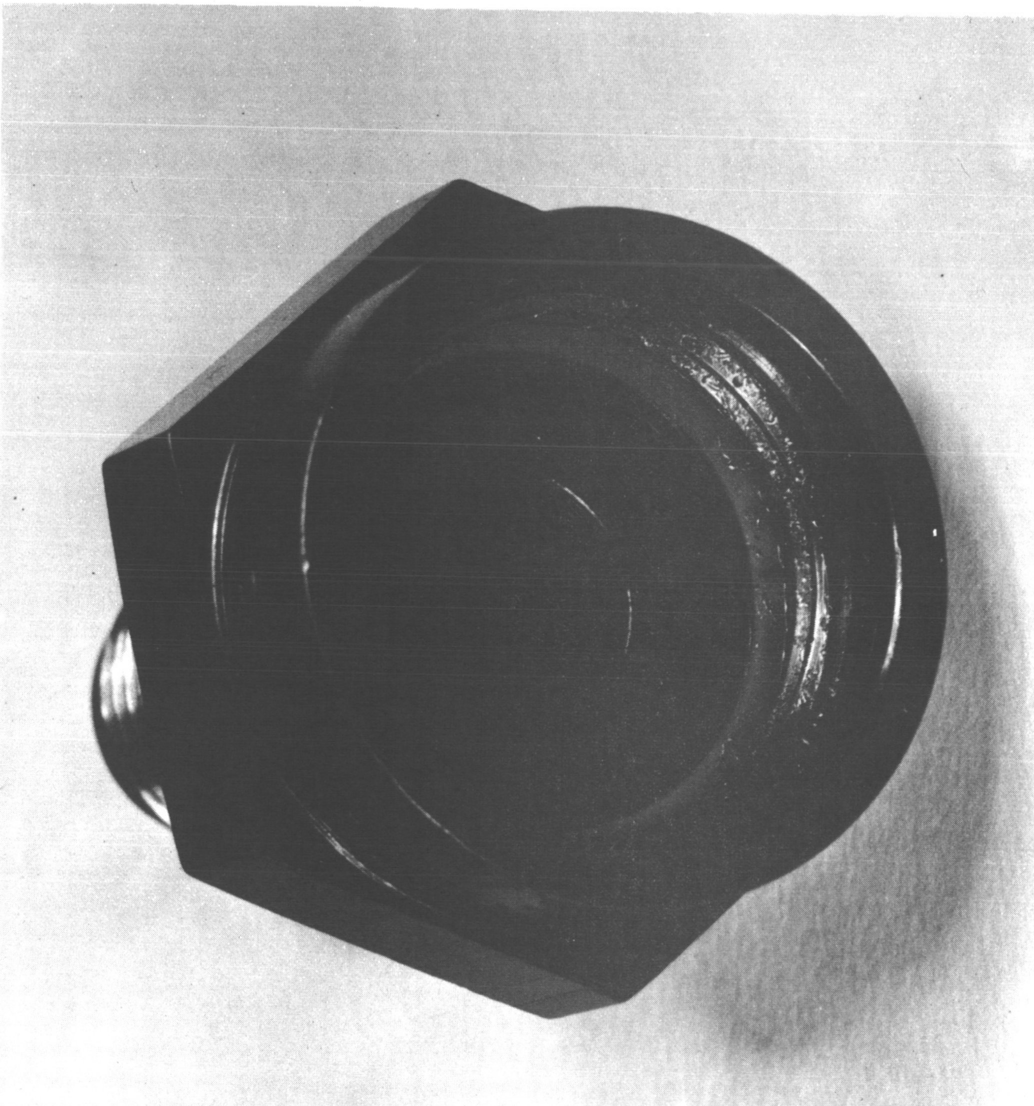

FIGURE 19. METAL CHIP CONTAMINATION ON INTERNAL THREADS

drilling operation for the hole had left a distorted sharp edge on the threads. Since the male fitting was made of stainless steel and the female fitting was made of aluminum, the metallic chips were cut from the female fitting threads as the two fittings were joined.

Figures 20 and 21 show the poor quality of two different type pressure switches that had failed on two of the Saturn Vehicles during checkout.

Because of the many valve problems encountered in the manufacturing of vehicles at MSFC, the Manufacturing and Engineering Division has created a Valve Clinic to repair, reservice, and modify, as required, all vehicle valves which are not returned to the vendors. At the present time the Valve Clinic is small and inadequate; however, bids are now out for construction of a new Valve Clinic that should provide the Manufacturing Engineering Division with adequate valve repair services.

The next few slides will show some of the operations in our present Valve Clinic.

Figure 22 shows one of the technicians checking a seal for defects prior to installation in a valve.

Figure 23 shows the assembly of some of the many solenoid valves used in the pneumatic measuring and control systems of the Saturn Vehicle.

Figure 24 shows a technician checking the operation of a LOX Relief Valve on the Pneumatic Test Console.

Figure 25 shows a technician checking the operation of the LOX Pre-Valve under cold test conditions.

Figure 26 shows the cold testing of a LOX Relief Valve.

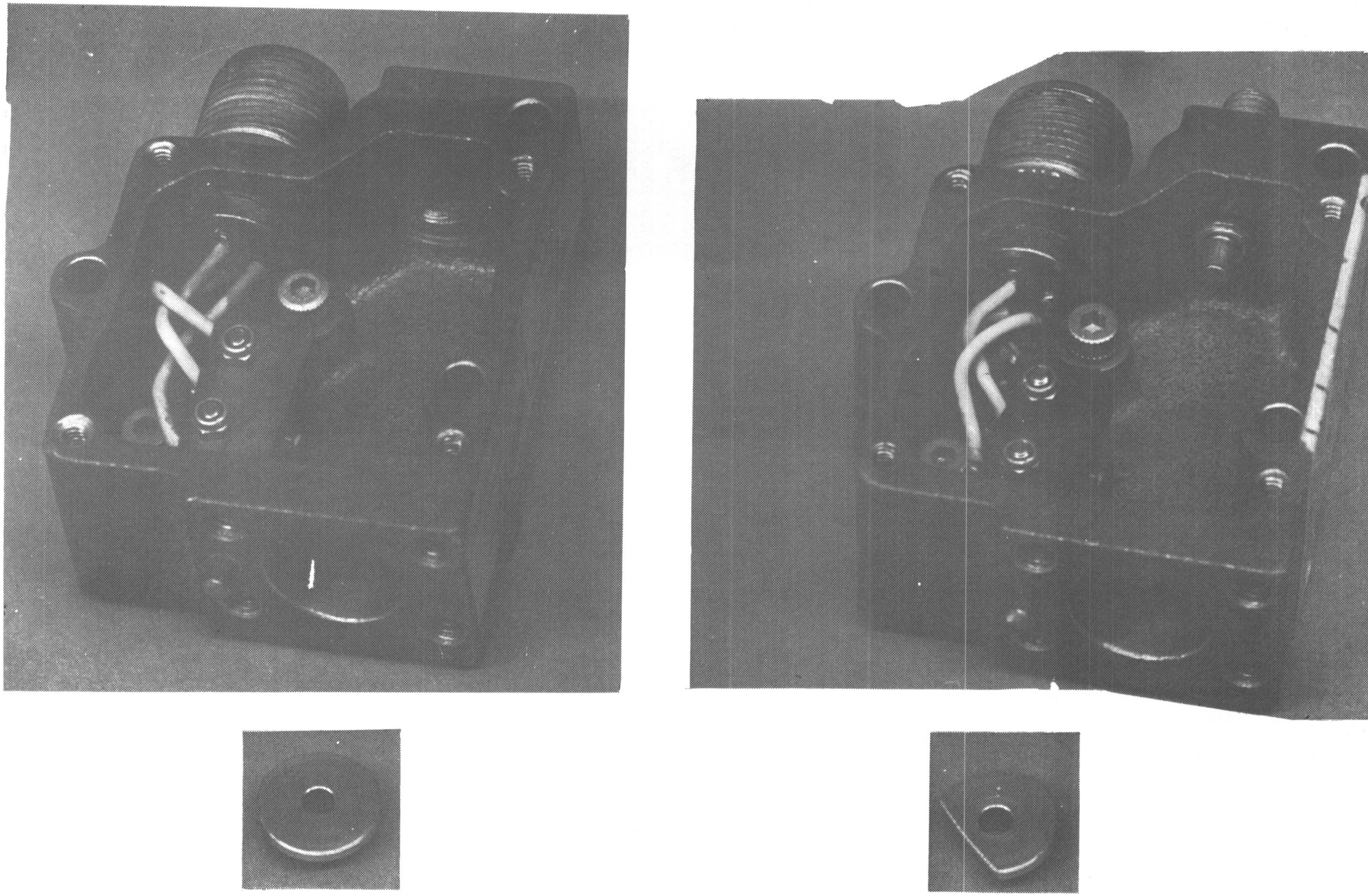

FIGURE 20. PRESSURE SWITCH MACHINING VARIATION REQUIRING REWORK OF SPRING SEAT

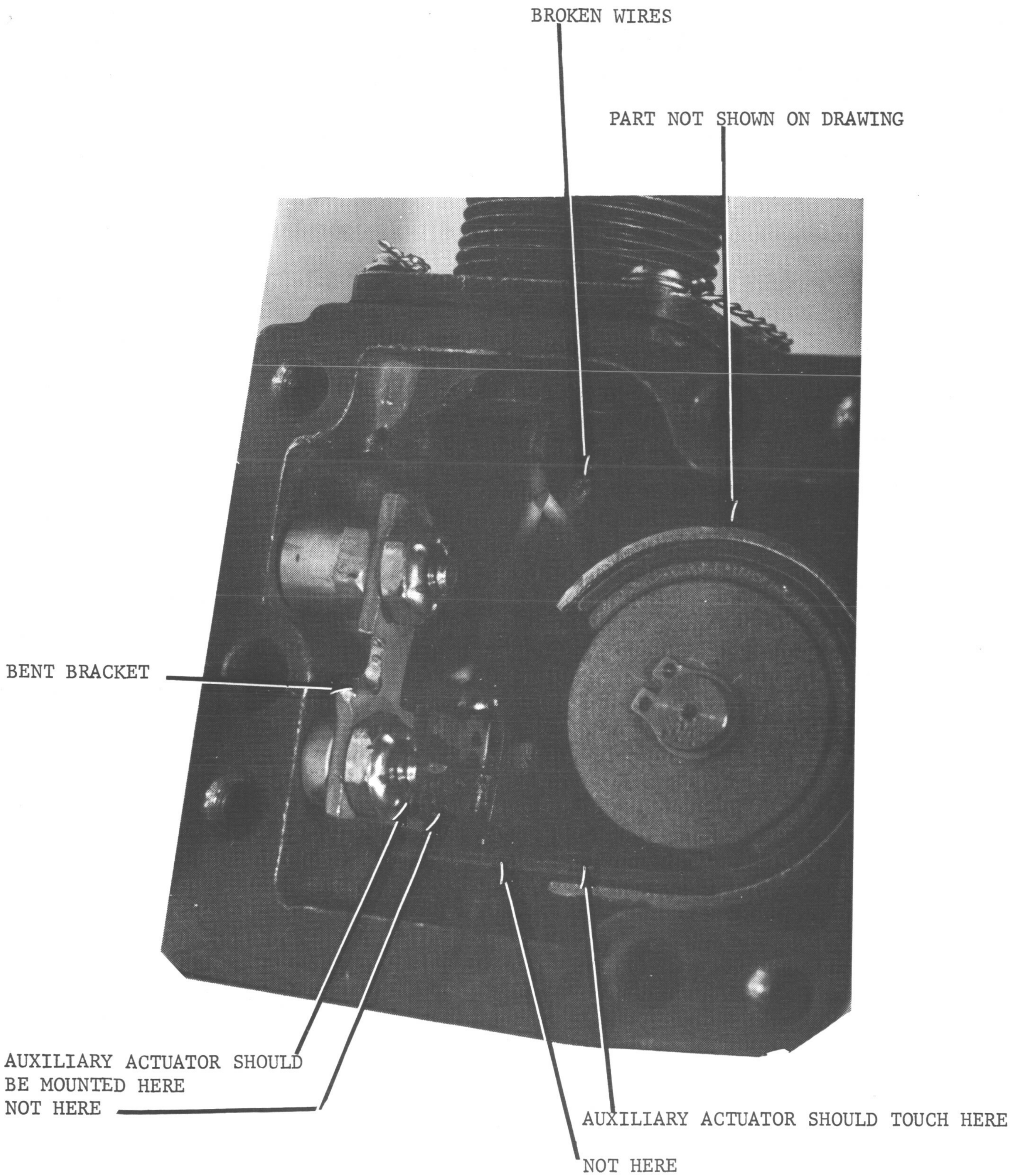

FIGURE 21. DEFECTS IN PRESSURE SWITCH

FIGURE 22. CHECKING A SEAL FOR DEFECTS PRIOR TO INSTALLATION IN A VALVE

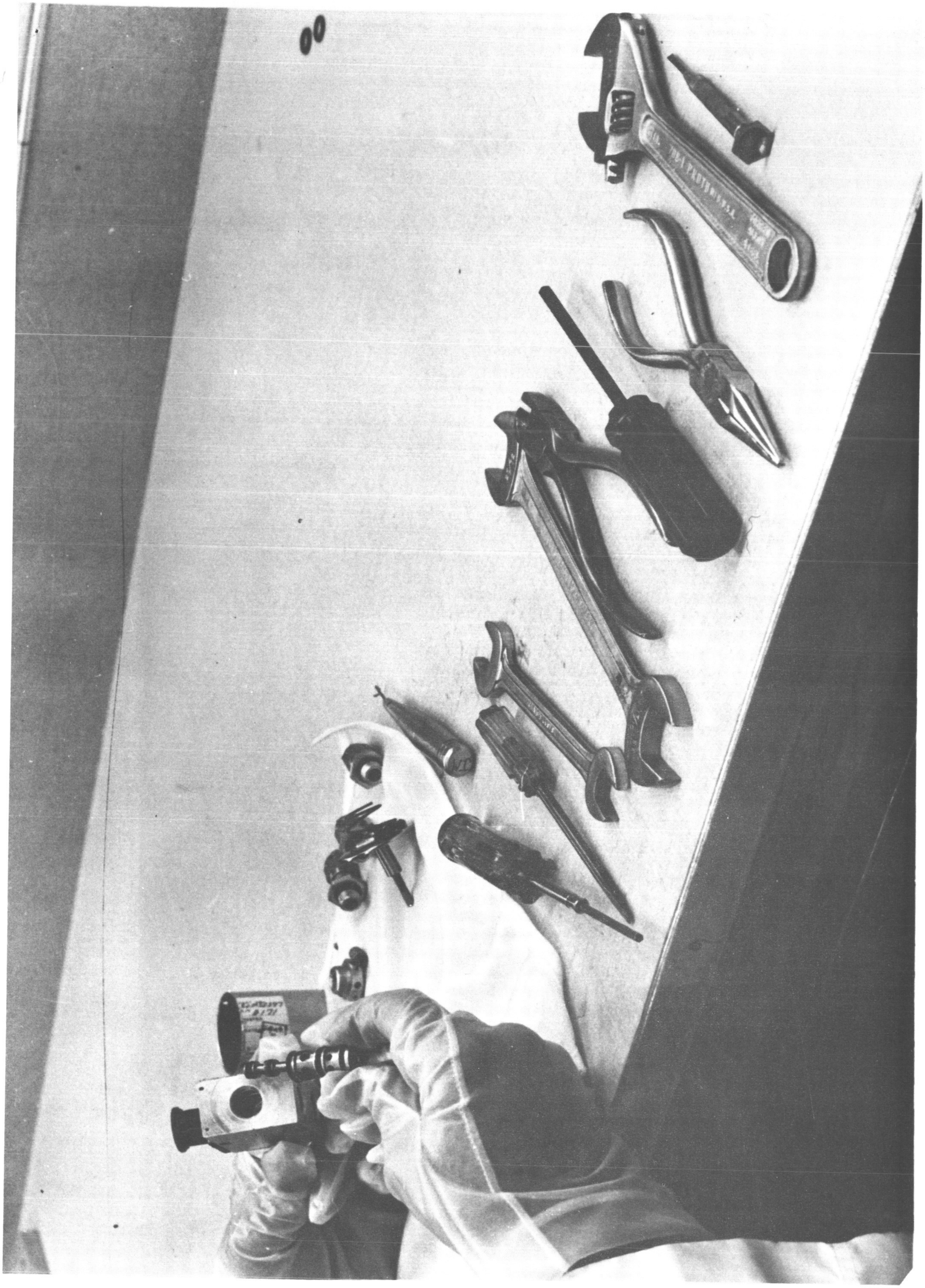

FIGURE 23. ASSEMBLY OF SOLENOID VALVES

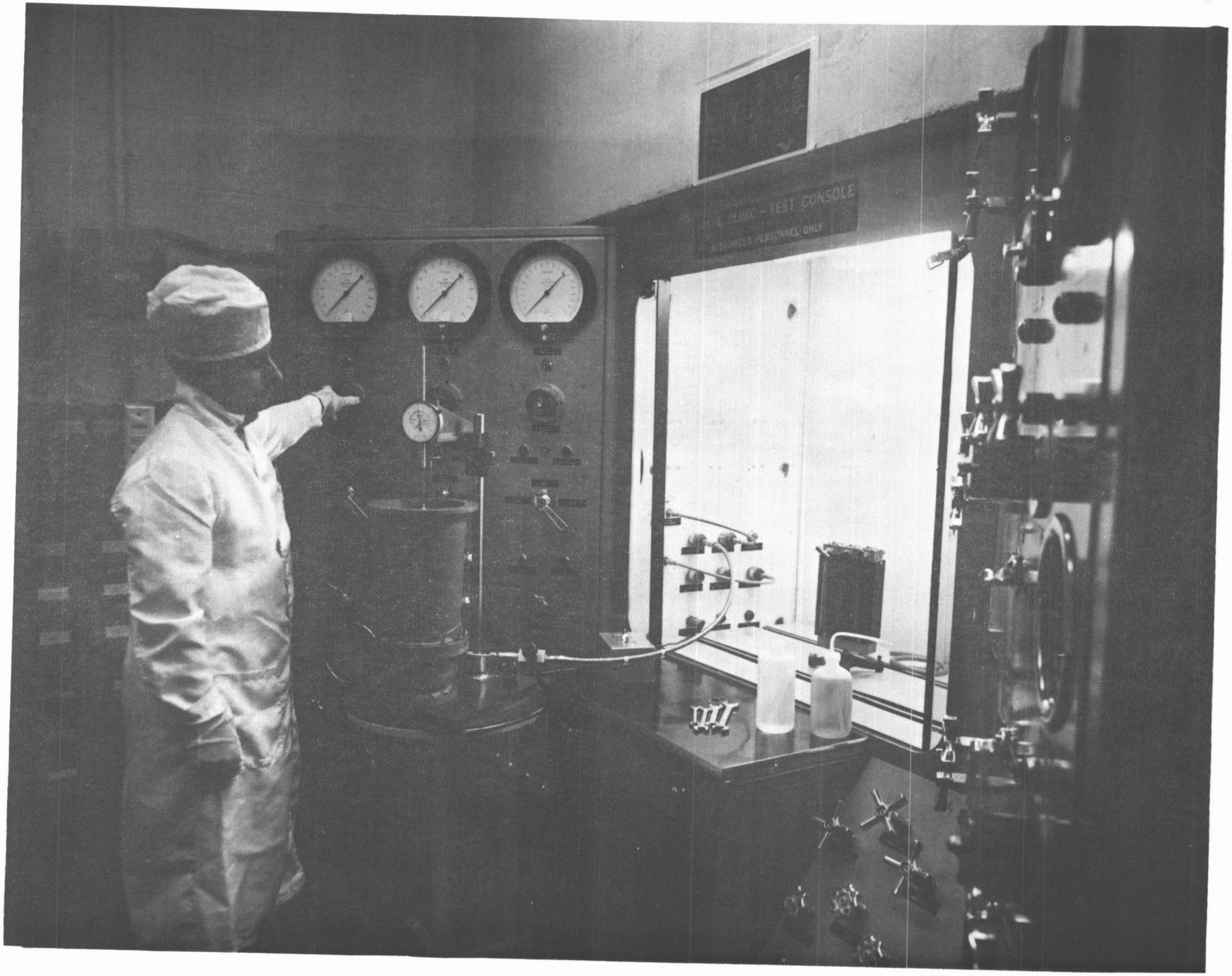

FIGURE 24. CHECKING THE OPERATION OF A LOX RELIEF VALVE ON THE PNEUMATIC TEST CONSOLE

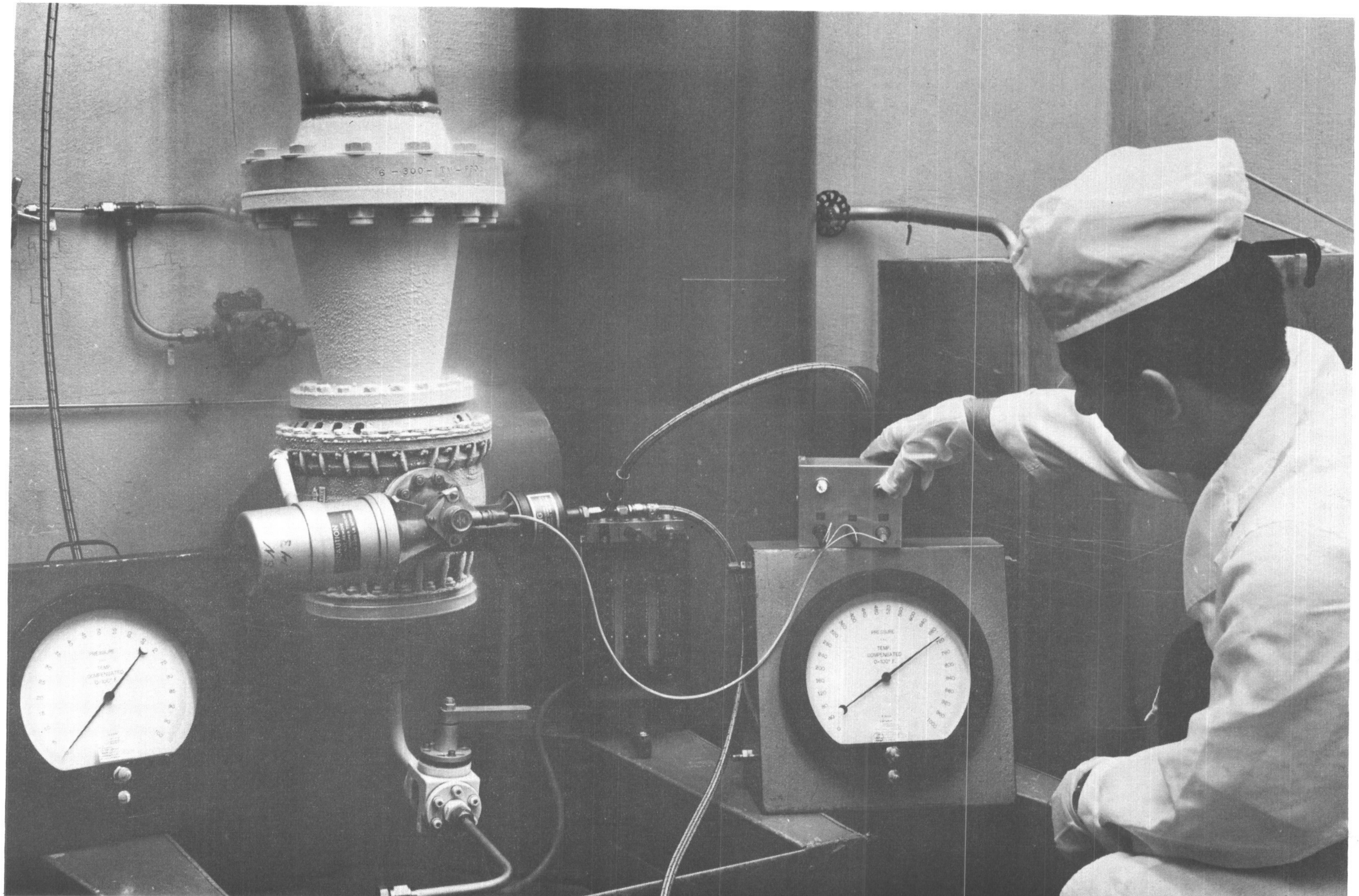

FIGURE 25. CHECKING THE OPERATION OF THE LOX PREVALVE UNDER COLD TEST CONDITIONS

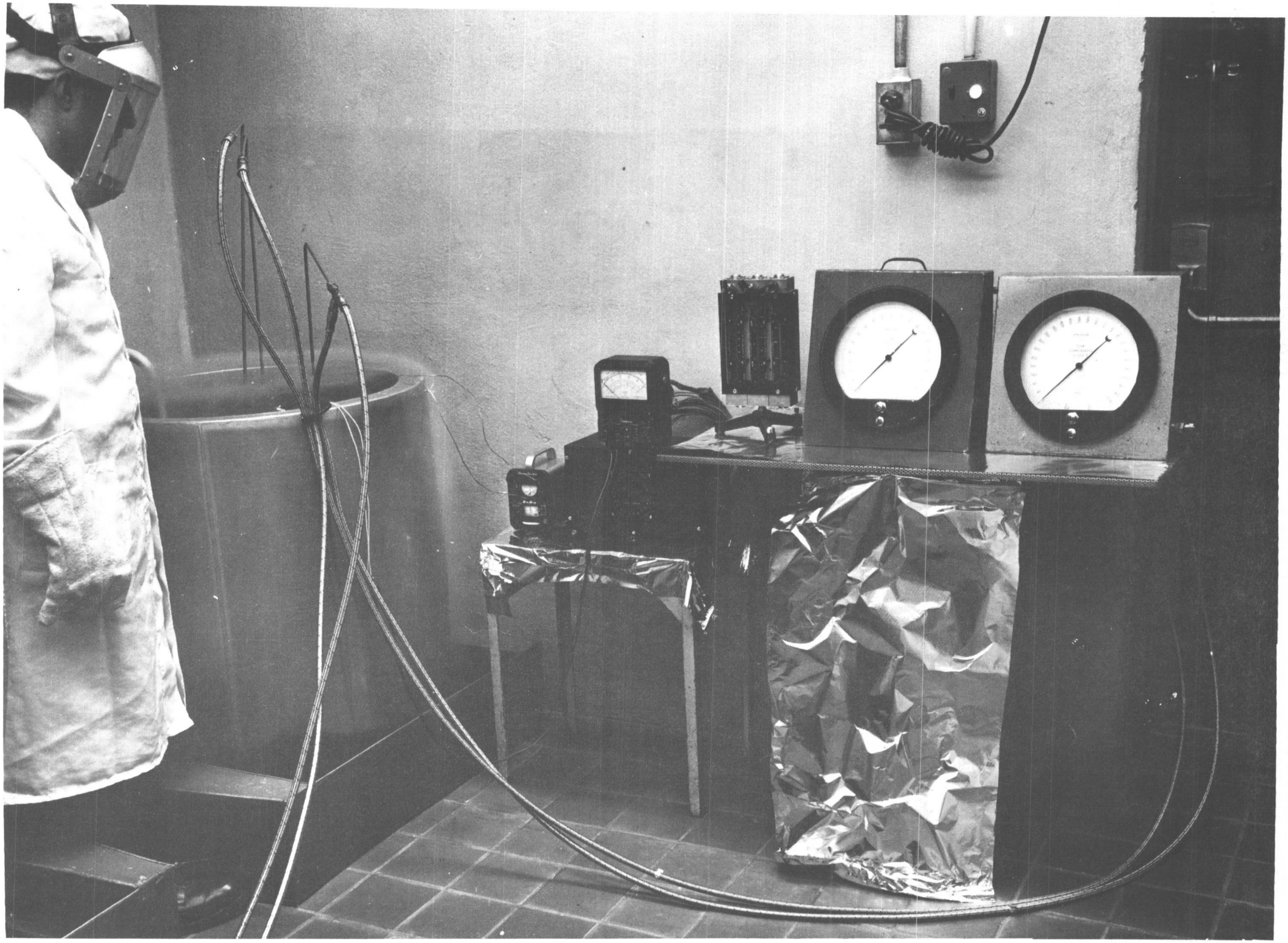

FIGURE 26. COLD TESTING OF A LOX RELIEF VALVE